

# Introduction of Mercury-free Gold Extraction Methods to Medium-Scale Miners and Education of Health Care Providers to Reduce the use of Mercury in Sorata, Bolivia

Peter W. U. Appel<sup>1</sup>, Astrid Andersen<sup>2</sup>, Leoncio D. Na-Oy<sup>3</sup>, Rudy Onos<sup>3</sup>

1 Geological Survey of Denmark and Greenland

2 Psychiatric Department, Central Hospital, Randers, Denmark

3 Mount Emerald Workers Cooperative of the Philippines

Corresponding Author:

Peter W. U. Appel,  
Senior Research Scientist,  
Geological Survey of Denmark  
and Greenland,  
Oester Voldgade 10, DK1350,  
Copenhagen, Denmark

Tel: +4523445498  
pa@geus.dk

## Introduction

Mercury is an extremely hazardous element. It spreads globally and accumulates in the ecosystem and thus poses a major threat to the future of humanity.<sup>1</sup> The global anthropogenic release of mercury to the environment comes from many sources, of which artisanal and small-scale gold mining (ASGM) is the biggest polluter, closely followed by the burning of coal. In Bolivia it is estimated that 120 tons of mercury are released annually into the environment from small-scale gold mining activities.<sup>2</sup> Mercury is used in ASGM for gold extraction (amalgamation). In 2009, 8.4 tons of

**Background.** Artisanal and small-scale miners in Bolivia release on the order of 120 tons of mercury annually. The mercury finds its way to the Amazon with catastrophic consequences for the biosphere. A project aimed at reducing the release of mercury was carried out in 2013 and 2014.

**Objectives.** The project had two objectives: to test whether the mercury-free gold extraction method could be an alternative to whole ore amalgamation in medium-scale mining in Bolivia and to teach mercury toxicology to health care providers in the gold mining area. The mercury-free gold extraction method has been successfully introduced in other countries, but mainly in very small-scale mining communities.

**Materials and Methods.** The targets in Bolivia were medium-scale miners processing over a hundred tons of ore per day. The chosen gold ores proved amenable to gold extraction using mercury-free extraction. Demonstrations of the mercury-free methods were carried out by processing similar quantities of gold ores using the amalgamation and the mercury-free method.

Miners, mining communities and local health providers were informed on the toxicity of mercury. Health providers were shown how to conduct epidemiological surveillance. Posters explaining the path of mercury from the processing stations to local households were prepared.

**Conclusions.** The gold ores tested during the project proved amenable to mercury-free gold extraction using borax smelting. The miners also realized that gold recovery increased when performing mercury-free gold extraction. The miners decided to stop using mercury and a follow-up project cleaned their mining equipment for mercury and modified the processing lines. The health care providers were also successfully trained.

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gold was extracted in Bolivia, of which ASGM produced 49%.<sup>3</sup>

Small- and medium-scale gold miners in Bolivia use the whole amalgamation method to extract gold. They add mercury directly into drums, where gold ore is milled by hard metal rods or balls. During milling, mercury captures the gold grains liberated during the milling process and forms a gold amalgam. The amalgam is separated from the milled ore and is then heated, whereby mercury evaporates and the

gold is left behind. The amalgamation process is an efficient and easy way to capture gold. There are, however, serious environmental and health problems with this process. The burning of amalgam releases mercury vapors into the environment. The mercury vapor is inhaled by the miners and by their immediate family. The milling process forms tiny mercury drops called mercury flour (*Figure 1*). Mercury flour cannot coalesce and therefore cannot be captured by the miners. Large amounts of mercury flour end

up in tailings littering the mining areas. The flour slowly evaporates and spreads throughout the environment. Another problem is that mercury flour floats on water and is carried away into the aquatic ecosystem which leads to possible mercury intoxication through consumption of contaminated fish. As mercury flour also contains large amounts of gold, the drawbacks of using mercury for gold extraction is twofold: loss of gold and deteriorating health.<sup>4</sup> Just living in an area with ASGM activity increases the risk of having elevated levels of mercury. Handling mercury as a miner or gold processor increases the risk of mercury intoxication.<sup>5</sup> Bolivia has signed the Minamata convention, an international treaty to protect human health and the environment from anthropogenic emissions, releases of mercury and mercury compounds. Bolivia is therefore obliged to take action to stop/reduce the use of mercury.<sup>6</sup>

An alternative to the amalgamation method is the borax-gravity method. This method was introduced in the Philippines about thirty years ago and rapidly gained momentum as about 25,000 miners started using it and continue to use it today. Recently, a three-year project in the Philippines convinced 1800 small-scale gold miners to convert from whole ore amalgamation to mercury-free gold extraction.<sup>7</sup> The method is simple and does not require purchase of expensive equipment. It uses more or less the same equipment that is used by whole ore amalgamation, but final steps use gravitational methods producing a gold concentrate. Smelting the concentrate with borax produces clean gold.

The main component of borax is boron. It has been argued that boron has adverse effects on the biosphere and should not therefore be used as a substitute for mercury in gold extraction. Boron treatment of rats, mice, and

ASGM

Artisanal and  
small-scale mining

Figure 1 — Mercury flour seen as small shiny spots in tailings

dogs has been associated with testicular toxicity, characterized by inhibited spermiation at lower dose levels and a reduction in epididymal sperm count at higher dose levels. A study was carried out on nearly 1000 men working in boron mining or processing in Liaoning Province in northeast China.<sup>8</sup> The study included individual assessment of boron exposure, interview data on reproductive experience and semen analysis. Employed men living in the same community and in a remote community were used as controls. The study showed that while boron has been shown to adversely affect male reproduction in laboratory animals, there is no clear evidence of male reproductive effects attributable to boron in studies of highly exposed workers.<sup>8</sup>

## Materials and Methods

### Steps Towards Reducing the Use of Mercury in Bolivia

This project, financed by the European Union and Danish Embassy in La Paz, was carried out in 2013 to find avenues to reduce/stop release of mercury from ASGM in Bolivia. The project aimed to generate and promote a culture of prevention in workers, their families and people in the areas of intervention towards a cleaner and profitable production. To do that it was necessary:

- To test whether the chosen gold ores in Bolivia are amenable to gold extraction using the mercury-free gold extraction method using borax smelting.



Figure 2 — Large drum milling many tons of gold ore per hour



Figure 3 — Shaking table producing heavy mineral concentrates

- Give health care providers basic tools to conduct epidemiological surveillance to get an idea of the level of the problem.
- Prepare booklets and posters for the community, broadcast advertisements on the radio and television, attend health fairs, create workshops, etc.

### Testing Gold Ore in Bolivia for Amenability to Mercury-Free Gold Extraction

Field work was carried out in Sorata in Western Bolivia where the La Suerte and San Mateo mines were visited. These mines are larger than typical small-scale mining operations seen in Africa, Southeast Asia and Central America, where mining is carried out by a few men with primitive tools. At La Suerte and San Mateo, gold mining and gold extraction is carried out on a much larger scale. Deep tunnels are excavated by heavy machinery and large trucks carry the broken ore to the processing sites, where large rotating drums crush many tons of rocks at a time (Figure 2) and feed large shaking tables (Figure 3). Mercury is added in large amounts to the drums and is captured by the shaking tables. The recovered mercury is burned and gold is recovered. Downstream from the shaking table, women are seen extracting mercury from the streams. The recovered mercury is burned and the gold recovered. This shows that large amounts of mercury (and gold) are lost to the environment and travel downstream, thereby polluting many of the larger rivers of Bolivia and finally end up in the area of the Amazon Basin.

### Demonstrating the Mercury-Free Gold Extraction Method

Miners were assembled and given a presentation on mercury-free gold extraction.<sup>4</sup> The miners were informed that the mercury-free gold extraction method using borax smelting is environmentally benign and as an

- If testing is positive, then demonstrate the method to small-scale miners showing that the mercury-free method yields higher gold recovery.

To support the change in the

community it was decided to:

- Teach health providers about mercury toxicology so that they would be able to attend the main risk groups: miners, women and children with possible mercury intoxication.



extra bonus will give higher gold recovery than amalgamation. The latter statement is of course easier said than demonstrated and the miners were skeptical of this claim.

The first step was to demonstrate the mercury-free extraction method. Miners from several mines in the area were assembled and shown how the method worked. They eagerly commented on how the process was carried out, but were still reluctant to adopt the method because they felt it was too time consuming. It was therefore decided to create a competition measuring the time required for the two gold extraction methods.

In order to convince the miners that they would capture more gold by the mercury-free method, two competitions were held. For each competition, about 50 kg of gold ore was crushed and milled using the mercury-free method. The milled material was placed in a tub and carefully split in two equal parts (*Figure 4*). The local miners added mercury to their share and the foreign team extracted gold using the mercury-free method with borax gold smelting as the last step (*Figure 5*). The time spent by both teams was carefully recorded and shown to be almost identical with less than 10% difference, with the amalgamation method lasting slightly longer.

## Results

In the first competition, the mercury-free method delivered 0.5 grams of gold, whereas the local team using mercury delivered 0.1 grams. In the second competition, the mercury-free method yielded 0.4 grams of gold and the amalgamation method recovered 0.3 grams of gold (*Figure 6*). The outcome of the competitions convinced the miners that changing to the mercury-free method would not require a longer processing time, but would increase their gold recovery.



*Figure 4 — Tub with milled gold ore ready for splitting into two equal parts*



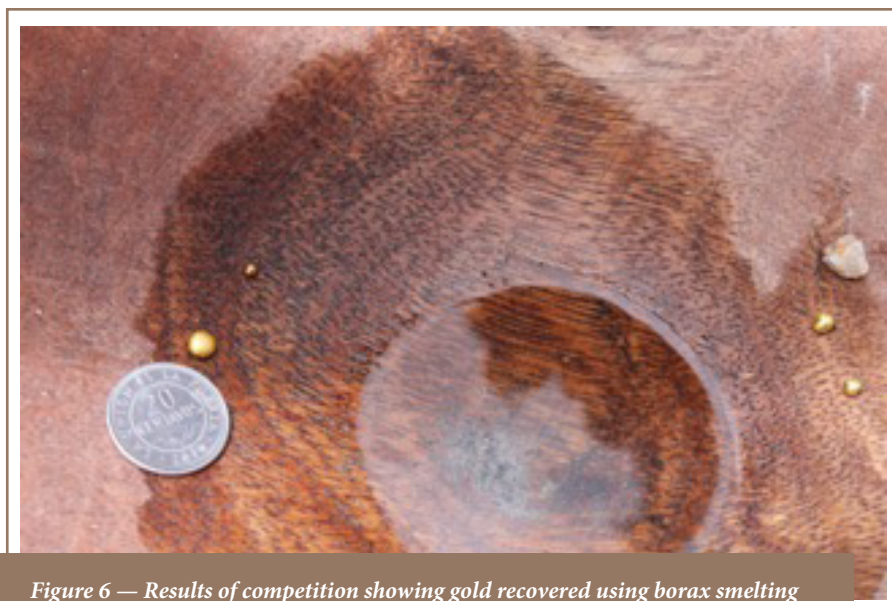
*Figure 5 — Smelting gold out of heavy mineral concentrate using borax*

The interest among the miners prompted an application for a follow-up project where two miners (Leoncio D. Na-Oy and Rudy Onos) from the Philippines helped the local miners to clean their processing plant of mercury and modify their plant so that they

could go mercury-free. That project was carried out in late 2014.

## Strengthening the Skills of Health Care Workers

To strengthen the skills of health care workers, two-day seminars were



*Figure 6 — Results of competition showing gold recovered using borax smelting and amalgamation. On the lower left side of the photo is the gold button recovered using borax smelting weighing 0.5 g, and above is the 0.1 g button recovered using amalgamation. On the upper right side of the photo is the 0.4 g gold button recovered using borax smelting, and below is the 0.3 g gold button recovered using amalgamation.*

by amalgamation and how the borax-gravity method could be an alternative. In addition, the toxicology of borax was discussed.

Strategies for dissemination of the information from the various health care centers were discussed and presented by the participants. Both artisanal- and small-scale gold miners and health care providers were interested. The health care professionals were especially interested in the fact that living in sites where there is gold mining activity increases the level of mercury in the body to dangerous levels. They were also interested in the clinical manifestations of mercury intoxication, indicating that mercury intoxication was a possible explanation for various cases of illness among their patients. After the seminar, a qualified physician stayed in the communities for one month, promoting mercury-free practices by teaching, leading discussions, creating radio programs and handing out educational materials.

#### Identification of Barriers

There are many challenges in the health care sector with regard to toxicology.

Questionnaires were handed out in the beginning of the seminar and interviews were conducted. Several barriers were identified:

- The level of knowledge of mercury toxicology is extremely low. It is not prioritized in the education of health care providers; some health care providers did not even know what mercury was.
- The health care centers use measuring devices containing mercury such as thermometers and sphygmomanometers. In the hospital in Sorata, an average of 50 mercury thermometers are broken every year.



*Figure 7 — Teaching a group of local health care providers*

held in the areas of intervention. The seminars were held in the town hall of Sorata. Twenty-three participants from 12 different health care centers and hospitals and one miner from a local mine participated (Figure 7).

Health care providers and the gold miner were educated on the symptoms of and possible treatments for mercury intoxication, prevention strategies and epidemiological surveillance. They were introduced briefly to gold mining

- No laboratories were equipped to analyze biological material for mercury. Therefore, it is not possible to diagnose mercury intoxication in the study area.
- There are no special departments to treat intoxication, and it is not possible to receive chelation therapy in Bolivia.
- Health care providers are not familiar with epidemiological surveillance, and there is no central database to collect possible cases of mercury intoxication.
- There is only one toxicology call center to help health care providers with toxicological problems, and it is staffed by only one part-time doctor.

### Follow-up Project

In August 2014, a follow-up project was carried out in the Santa Domingo mine in the Sorata area. The project was comprised of installation of a mercury-free plant and was designed to teach small-scale gold miners to extract gold with mercury-free methods using borax smelting in the final step.

The mercury-polluted plant at Santo Domingo was thoroughly cleaned, making sure that no mercury was left throughout the entire processing line.

The next step was demonstrating the mercury-free method. Some of the miners were selected to carry out this process. Miners who showed the most skill with the new process were selected to be trainers and were given additional training so they could carry out all aspects of the process.

### Conclusions

The gold ores in the Sorata region from La Suerte and San Mateo are amenable to gold extraction using borax smelting. The gold ores from the two mines are very similar. Two competitions between traditional

mercury gold extraction and mercury-free gold extraction methods were held and the mercury-free method gave the highest yield in both cases. The processing time of the two methods were approximately the same. The miners at Santo Domingo were convinced of the advantages of switching to mercury-free methods. They invested many working hours cleaning their processing line of mercury so they could start extracting gold using mercury-free methods.

Health care providers face great challenges attending patients with possible mercury intoxication. It is not currently possible to verify the diagnosis of mercury intoxication in Bolivia. There are no specialized units in hospitals which offer toxicological assistance or provide chelation therapy. There is only one center with toxicological information in Santa Cruz, Bolivia.

This is problematic because it makes it very difficult to get an estimate of the extent of the problem. It is a vicious circle. Since the problem is not prioritized on a national political level, it is not prioritized in the universities. Health care providers do not conduct epidemiological surveillance, making it impossible to give an estimate of the proportion of the problem, thus making it difficult to attract political attention to the problem. As a result of the project described above, health care providers in the Sorata region could begin to break this circle.

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